MASTER OF SCIENCE
IN
OPERATIONS RESEARCH

AN ANALYSIS OF PURCHASE CARD RECONCILIATION TIMES
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Effective 1 October 1997, the Government Commercial Purchase Card was mandated for micro-purchases of commercial items (procurement valued at or below $2,500). As of August 1999, 97% of Navy activities use purchase cards for micro-purchases. During fiscal year 1998, these activities used the purchase card in over 1,996,000 transactions valued at $1.055 billion dollars. Overall, purchase card implementation has been an overwhelming success, drastically reducing administrative costs and providing a streamlined procurement process. Even though efforts have been made to refine the reconciliation process to help government activities avoid unnecessary interest payments, there are still many potential improvements. The government purchase card is similar to standard issue credit cards, so interest accrues on delinquent invoices. During the fourth quarter of fiscal year 1999, the U.S. Navy paid $323,000 in interest payments due to delinquent invoices. Of this total, the activities under CINCLANTFLT were responsible for $58,000 and those under CINCPACFLT were responsible for $43,000. A combination of data analysis and systems analysis techniques are used to define the reconciliation process, to suggest process improvements, and to recommend tools to better manage the reconciliation process.

DoD KEY TECHNOLOGY AREA: Other (Financial Reconciliation)

KEYWORDS: Government Purchase Cards, IMPAC Card, Statistical Process Control

AN ANALYSIS OF THE IMPACT OF FULLY FUNDED GRADUATE EDUCATION ON THE RETENTION OF NAVAL OFFICERS
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This thesis investigates the impact of "funded graduate education" on retention of Naval Officers. Logit regression and multivariate models were used to determine the effects that a graduate degree from the Naval Postgraduate School (fully funded) or civilian graduate schools through partially funded graduate programs had on officer retention. The data sets were created using data from the Officer Master Record Files (OMRF) obtained from the Defense Manpower Data Center, Monterey, California (DMDC). The data sets included all Naval Officers that were eligible for voluntary separation each year from 1992 to 1997.

Maximum likelihood logit regression was used to estimate the probabilities that officers with graduate degrees earned from NPS or civilian institutions decide to leave the service at the end of any mandatory educational obligation. The findings revealed indicate that although funded graduate education may have

an effect on promotion possibilities, its impact on retention past the ten-year point in an officer's career is not detectable.

DoD KEY TECHNOLOGY AREA: Manpower, Personnel, and Training

KEYWORDS: Graduate Education, Retention, Subspecialty, Postgraduate Degree

ASSIGNING UNMANNED UNDERSEA VEHICLES TO MINE DETECTION OPERATIONS

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In an era when mines are inexpensive and easily accessible, present and near-term mine detection and area reconnaissance capabilities are insufficient to enable unencumbered maneuver in the littoral regions. Unmanned undersea vehicles (UUVs) possess potential to provide tactical commanders with full understanding of the mine threat without risk to ships or personnel and without exposing intentions. By integrating an assortment of emerging capabilities, a system comprised of a variety of UUVs could address this growing mine threat. This thesis develops and implements the Mine Reconnaissance System Assessment (MiRSA) model, a mixed integer-linear program to assign a mix of UUVs to search areas within a suspected minefield area. This thesis compares combinations of two Long-term Mine Reconnaissance System (LMRS) vehicles, six Remote Environmental Monitoring Units (REMUS) vehicles, and a notional Manta vehicle searching a 262 square nautical mile area in the Straits of Hormuz. MiRSA finds the two LMRS vehicles can complete a 95% confidence level search in 91 hours, the Manta vehicle can complete the search in 130 hours, and the two LMRS vehicles with Manta employed optimally together require only 52 hours. At a 99.99% confidence level search, Manta operating alone requires 298 hours (approximately 12 days) while optimal employment of the two LMRS, six REMUS, and Manta vehicles together can finish the search in only 104 hours.

DoD KEY TECHNOLOGY AREA: Other **(**Unmanned Undersea Vehicles)

KEYWORDS: Unmanned Undersea Vehicle, Long-term Mine Reconnaissance System, Remote Environmental Monitoring Units, Manta, Mine Detection

ASSESSMENT OF SHALLOW WATER INFLUENCE MINESWEEPING SYSTEM (SWIMS) IMPLEMENTATION UTILIZING CH-60

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The Sikorsky H-60 airframe is planned to be the only rotary-wing aircraft in the Navy's inventory through 2015. The CH-60 variant will support the Airborne Mine Countermeasures (AMCM) mission, replacing the current MH-53E and it's MK-106 towed influence system. The CH-60's towing capacity will be significantly less than the MH-53E, so new equipment, designated the Shallow Water Influence Mine Sweeping (SWIMS) system. Capability of SWIMS is expected to be significantly less than that of the MK-106 system. Smaller size and aircraft commonality will enable SWIMS to deploy on most surface combatants, providing forward presence and reducing employment time of an AMCM suite into a Mine Danger Area (MDA).

The purpose of this study is to analyze the feasibility of, and the trade-off possibilities for, different types of AMCM operations using the CH-60 and SWIMS system. Given the planned limited capabilities of the CH-60/SWIMS system relative to the MH-53E/MK-106 system, we explore methods for determining;

(i) how to operate CH-60/SWIMS using proposed new employment methods, (ii) how many CH-60's will be required to clear a specified MDA, and (iii) how to minimize the operational impact to the ships involved.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Sensors

KEYWORDS: Airborne Mine Countermeasures, Helicopter Employment Techniques, Decision Making and Forecasting, Use of Force Modeling

DESIGN AND ANALYSIS OF A SHIPBOARD VISUAL NAVIGATION AID FOR VESSELS IN FORMATION

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This thesis examines the development and analysis of a specialized lighted visual navigation aid, called Tactical Vectoring Equipment (TVE), designed to assist shipboard conning officers when maneuvering in a battle group formation. Piloting at night in close proximity to another vessel can be one of the most challenging and dangerous evolutions at sea. In particular, one of the most demanding tasks is nighttime plane-guard duty. During this evolution, the conning officer utilizes voice radio communications, radar, and visual navigation aids to maintain proper station astern of an aircraft carrier and make maneuvering decisions. However, these visual cues and navigational aids can be ambiguous or late. Conning officers can experience situational disorientation with their attention distributed between tracking the carrier and other bridge duties. At night, the loss of contrast sensitivity, the lack of daytime visual cues and confusing ship silhouettes can hinder determination of range, course, speed and target angle. A virtual environment computer model was used to design the specialized navigation aid and measure its effectiveness on subjects. The TVE light display resulted in significantly less range and bearing errors compared to normal navigation lights. This reduced human error, improved ship-handling accuracy and enhanced situational awareness. This is an effective, versatile, and inexpensive device that should be seriously considered for future development and implementation in the fleet.

DoD KEY TECHNOLOGY AREAS: Human Systems Interface, Sensors, Surface/Under Surface Vehicles - Ships and Watercraft

KEYWORDS: Visual Navigation Aid, Navigation Lights, Plane Guard Duties, Night Vision, Human Performance

PLANNING CAPITAL INVESTMENTS IN NAVY FORCES

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Naval spending has always involved large amounts of resources, research and technology, money, and the attention of civilian and military leadership. In 1794 the Congress authorized $800,000 (1794 dollars) to construct six frigates. Today, an attack submarine costs more than $2 billion, an aircraft carrier more than $5 billion, and its air wing $5 billion more. These ships are the only current American clients for nuclear power plants. The Navy must balance these large capital expenditures with other procurements and maintain an industrial base capable of producing these unique warships. The Navy currently manages these complex interplays via the Integrated Warfare Architecture Assessment Planning Process (IWARS). Force Structure, an IWARS component, views a 25-year horizon at the platform level using the Extended

Planning Annex/Total Obligated Authority Model (a spreadsheet model that estimates the financial impact of any complete future plan). This thesis presents an integer-linear program, the Capital Investment Planning Aid (CIPA), that extends EPA/TOA with optimization. CIPA explores all alternatives while considering budget restrictions, industrial base requirements and restrictions, and force level requirements. CIPA is tested with a 25-year planning horizon with eight mission areas, 19 ship classes, five aircraft types, five production facilities, and three categories of money. A current base case and several excursions demonstrate CIPA can be used to address exigent issues optimally.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Operations Research, Integer Programming, Procurement, Capital Investments, Military Capital Budgeting, Optimization

A HEURISTIC FOR LAND-ATTACK PREDESIGNATION

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Predesignation is the assignment of land-attack missiles on surface ships and submarines to target aim points. The assignment process has two stages: (1) the allocation of land-attack missiles to launch platforms, considering all tasks and platforms simultaneously; and (2) given this preliminary allocation, the refined assignment of land-attack missiles to tasks aboard an individual platform, separately considering each platform and the associated allocations obtained from (1). This thesis addresses only the *first stage*, i.e., the automated allocation of land-attack missiles to surface ships. Currently, strike planners possess no tools that yield consistent and reproducible assignments. Two previous NPS models address the allocation of tasks to launch platforms. One does not address details such as multiple launch areas or multiple time periods, and the other proposes a model that is too computationally expensive to implement in an operational setting. In this thesis, a tool is developed to yield allocations similar to those obtained with the latter model in a much shorter amount of time.

DoD KEY TECHNOLOGY AREAS: Command, Control and Communications, Conventional Weapons

KEYWORDS: Tomahawk Land-Attack Missile, Heuristic, Weapons Allocation

SENSITIVITY ANALYSIS OF THE TOPOLOGY OF CLASSIFICATION TREES

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The use of classification trees is one of the most widely used techniques in classification. It is well known that classification trees are not stable in their topology, in contrast to their robustness with respect to misclassification rate.

This thesis defines a measure that compares the topology of two trees and studies how a tree's topology changes when the dependent (Y) variable or the independent (X) variables are perturbed. This allows us to examine the "robustness" of tree topology under perturbation and to compare it to the robustness with respect to the misclassification rate under the same perturbations.

We show that the tree topology can change significantly even for small perturbations in many sets of data. This suggests that even small measurement errors in the variables can affect the tree topology greatly. Because data are often measured with error, it follows that splitting rules in trees may not be suitable for use in making policy decisions. We propose a measure for tree topology, and show that tree topology

changes faster than the misclassification rate does under mild perturbations. This finding formalizes the concept that tree models are more stable in terms of misclassification rate than in terms of topology.

DoD KEY TECHNOLOGY AREA: Other (Statistics)

KEYWORDS: Classification Tree, Sensitivity Analysis

ADVANCED NAVAL SURFACE FIRE SUPPORT WEAPON EMPLOYMENT AGAINST MOBILE TARGETS

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Key threat trends have identified shortfalls in Naval Surface Fire Support (NSFS), a mission area that is undergoing rapid evolution. The Navy's ability to effectively provide sea-based fire support to ground forces is profoundly challenged by mobile and reduced dwell time targets. Furthermore, longer range enemy weapon systems, which must be destroyed at greater ranges prior to their engagement of friendly forces, will make NSFS timeliness a difficult proposition. To overcome these threat trends, the United States is developing sophisticated weapons that promise increased lethality, greater ranges and improved responsiveness. However, the development of robust firing policies to ensure effective weapon utilization has lagged behind the hardware. Existing computer models and simulations have not addressed the question of NSFS gun/missile firing policy. This thesis develops the Naval Surface Fire Support Simulation (NSFSSim) model, a discrete-event simulation that serves as an analysis tool to determine favorable firing policies for future NSFS gun and missile systems in support of determining the appropriate NSFS weapons mix. NSFSSim models ships and their associated NSFS weapons in counterbattery and call fire missions against mobile, reduced dwell time targets. Exploratory analysis using NSFSSim yields useful insights, and the component-based architecture underlying the model provides significant flexibility for further analysis.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Conventional Weapons, Modeling and Simulation

KEYWORDS: Discrete-Event Simulation, Firing Policy, Java, Modeling and Simulation, Naval Surface Fire Support

AN EXPLORATORY ANALYSIS OF THE MILITARY VALUE OF INFORMATION AND FORCE

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This thesis addresses the military value of information in conflict. It is composed of three complimentary experiments. The first experiment uses a simple contest to assess how military decision makers perceive and use information. The results of the experiment demonstrate that military decision makers do not always use information optimally. Equally insightful, military decision makers significantly overestimate the value of information compared to force advantage. The second experiment is an exploratory analysis of like naval surface forces and explores the value of information versus force advantage in modern naval surface combat using a computational model of naval missile combat. The results of the exploratory analysis of like naval forces suggest that increasing information advantage can enhance but occasionally may degrade a force's effectiveness. In contrast, increasing force advantage in the same conflict always

enhances the combat effectiveness of the forces investigated. The third experiment analyzes a more realistic asymmetric scenario. In this case study, American aegis-type ships engage more numerous coastal defense-type forces. The results show the advantage of numbers even when the aegis-type ships have virtually total information.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Information, Simulation, Naval Combat

EXPLORATORY MODEL ANALYSIS OF THE SPACE BASED INFRARED SYSTEM (SBIRS) LOW GLOBAL SCHEDULER PROBLEM

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Proliferation of theater ballistic missile technologies to potential U.S. adversaries necessitates that the U.S. employ a defensive system to counter this threat. The system that is being developed is called the Space-Based Infrared System (SBIRS) "System of Systems." The SBIRS Low component of the SBIRS “System of Systems” will track strategic and theater ballistic missiles from launch to reentry and relay necessary cueing data to missile interceptors before the missiles reach friendly forces or countries whose safety is a vital interest to the U.S. SBIRS Low has a number of critical system requirements that for any given satellite are mutually exclusive for the length of time needed to complete the specified tasking. This limitation implies a system capacity on the total number of ballistic objects the SBIRS Low system can track at any given time. Applying exploratory model analysis, the SBIRS Low model uses the Monte Carlo method to explore large regions of the model space to identify key factors in the system and to provide insight into different tasking schemes for individual satellites. The exploratory model analysis, which consisted of 13,760,000 missiles being tracked in the analysis of the CSS-2 and M-9 missiles, yielded the following significant results: (a) defining the “best” satellite is nontrivial, (b) the SBIRS Low system was unable to initiate a booster track for an unacceptably large percentage of M-9 missiles launched near the equator, (c) if the system anticipates a long delay in revisiting a track, a stereo view should be scheduled immediately prior to the start of the delay, (d) mono viewing alone does not provide the required track accuracy, (e) track accuracy is a function of missile classification, and (f) the instantaneous track accuracy versus sensor revisit rate does not fit any well-known probability distribution.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Ballistic Missile Defense, Exploratory Model Analysis, Space-Based Infrared Systems

IDENTIFICATION AND EVALUATION OF ORGANIZATIONAL STRUCTURES AND MEASURES FOR ANALYSIS OF JOINT TASK FORCES

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Joint Task Force (JTF) operate in a variety of missions and uncertain environments. The architectures these organizations must be capable of adapting to changes in the mission, the environment, or the organization itself. Mathematical models that are useful in predicting operational performance are needed

for research into the optimum design of a JTF architecture for a given mission. To develop these models, properties of a joint task force organization must be understood and measures must be identified that are both sensitive to changes (differences) in architectures and related to operational performance.

A literature review of civilian research in organizational structures and measures identified several candidates. To analyze the usefulness of these measures to identify differences in operational architectures, to known contrasting JTF organizations are developed using structures found in the literature. Each of the measures is applied to all structures in both architectures and analyzed to determine which measures show promise. Those that identify differences between operationally relevant architectures are deemed useful measures. Limited data from a related Naval Postgraduate School command and control experiment, in which architecture type is a factor, is used to fit a regression-type model that predicts JTF performance based on measures classified as useful.

DoD KEY TECHNOLOGY AREA: Command, Control, and Communications

KEYWORDS: Organizational Architectures, Organizational Measures, Organizational Structures, Joint Task Force Organization, Measures of Performance, JTF for 2010

MODELING AND SIMULATION SUPPORT FOR THE OPERATIONAL TEST AND EVALUATION OF A TACTICAL AIRBORNE RECONNAISSANCE SYSTEM

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Today's decreasing defense budget has forced the military to reduce its spending on operational testing of new equipment, among many other areas. Reduced testing has forced evaluators to focus their attention on possible sensitive issues prior to and during testing of new equipment. The Simulation, Test, and Evaluation Process implemented in 1995 to help reduce testing costs has been an integral part of the test and evaluation process.

This thesis develops a stochastic simulation to determine the sensitive aspects of operating and maintaining a mobile reconnaissance platform, specifically a helicopter, prior to and during actual testing. The simulation can also be implemented to compare the effectiveness of different mobile reconnaissance platforms instead of conducting side-by-side testing of actual platforms.

This simple, stochastic, event-driven simulation may be used to conduct sensitivity analysis on system design and operational issues, including attrition, for mobile reconnaissance platforms in order to focus the attention of the testers and evaluators on sensitive issues during testing.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Modeling and Simulation

KEYWORDS: Modeling and Simulation, Maintenance and Repair, Mobile Reconnaissance Platform, Attrition, Non-homogeneous Poisson Process, Operational Test and Evaluation, Java, Simkit

PREDICTING CASUALTIES IN SIMULATION MODELS ("COSAGE") USING DISCRETE-TIME ANALYTICAL MODELS

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The Army's Combat Sample Generator (COSAGE) is a two-sided, symmetrical, high-resolution stochastic simulation model that projects the outcome of ground combat between two forces. Blue force is typically a division; Red force size may be scaled from a fraction of a division to a combined arms army. Because COSAGE is high-resolution (many asset types), it requires extensive data preparation time, and because output is the result of 16-20 replications, substantial simulation run-time.

The analytical model implementation of this thesis is developed to economically project ground combat attrition and munitions expenditures beyond the 48-hour period currently modeled in COSAGE. The implementation evaluates Bayesian estimators of time-period survivorship to estimate expected numbers of kills, both friendly and enemy, during the first 48 hours of combat, then extrapolates those estimates in discrete time steps (here 24 hours) beyond 48 hours. The implementation can be used to project COSAGE output for all combat postures in Northeast and Southwest Asia (NEA and SWA respectively).

An application of the current implementation is to support the warfighting Commanders in Chief (CinC) need to create a Phased Threat Distribution (PTD) in accordance with the Capabilities-Based Munition Requirement Process introduced in June 1997.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Munition, Combat Sample Generator, Phased Threat Distribution, Capabilities-Based Munition Requirement Process

STATISTICAL MONITORING OF POLICE FORCE FOR RAPID DETECTION OF CHANGES IN FREQUENCY

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U.S. Law enforcement agencies are authorized and expected to use the minimum level of force required to maintain law and order. Few civilian law enforcement agencies and no military law enforcement agencies proactively monitor the use of force. Furthermore, agencies that do monitor force use methods that produce simplistic data summaries. These data summaries provide late and limited information to decision-makers regarding conditions sufficient to warrant managerial intervention. This study models police force incidents as a Poisson process and monitors the process to detect departures from the model. Police force data is charted using a self-starting control chart scheme. The charts assist the decision-maker in determining if intervention is necessary to correct an out-of-control condition while simultaneously minimizing unnecessary intervention when shifts in the frequency of force are plausibly due to random variation. Force data from military and civilian law enforcement agencies illustrate the methods. Methods are implemented in a Microsoft Excel spreadsheet with Visual Basic macros for ease of use.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Other (Quality Control)

KEYWORDS: Control of Excessive Force, Statistical Process Control, Control Chart Methodologies, Use of Force Modeling